FLORIDA STATE UNIVERSITY

Overview: Studies of Nuclear Structure and Nuclear Astrophysics

- Ingo Wiedenhöver

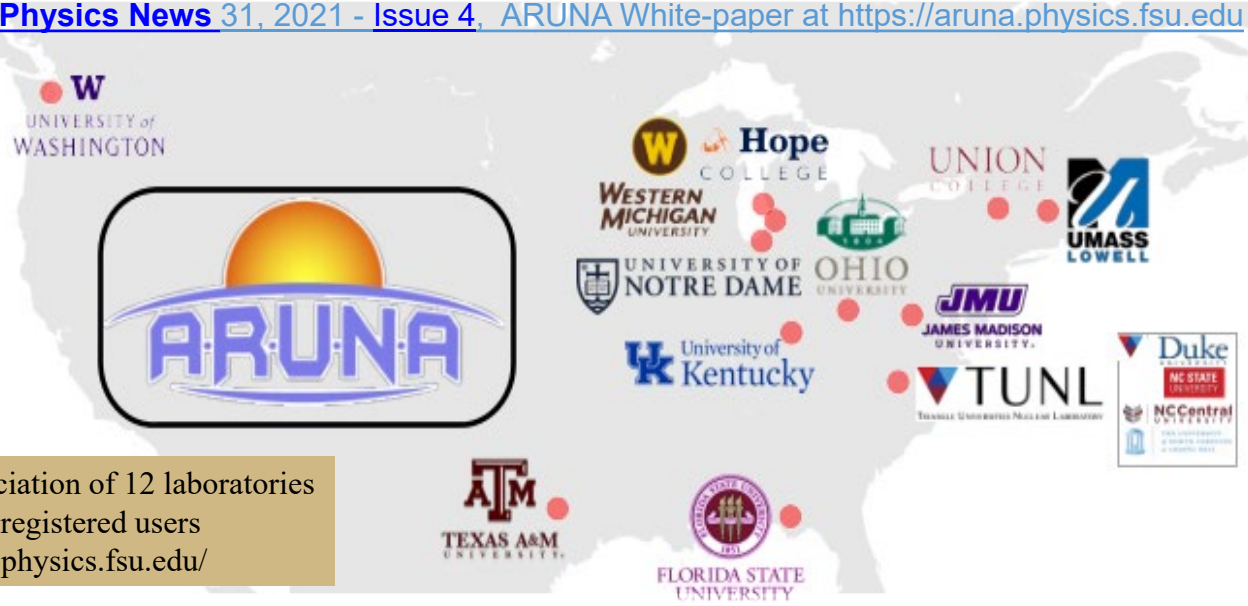
- NSF Site Visit, John D. Fox Laboratory, Florida State University

The role of the FSU Group in Nuclear Science

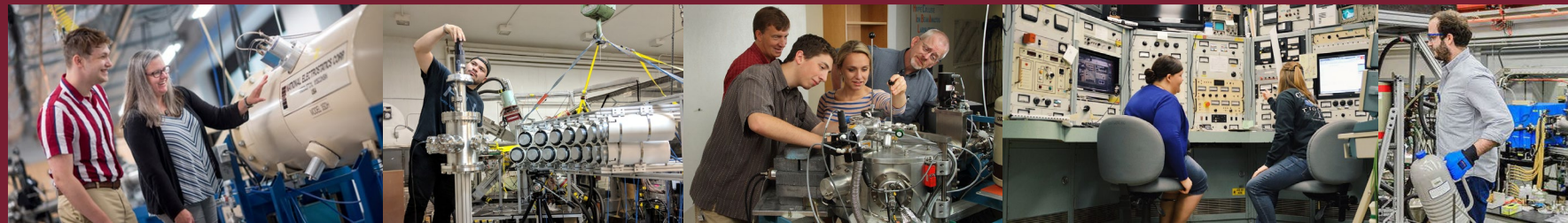
- Our science goals are the goals of the field, both at our laboratory and when we use the national facilities.
- We are leaders in ARUNA, which represents university laboratories in the national science community: White paper for LRP
- We produce first-rate science by focusing on the strengths of our laboratory and the fore-front opportunities at national laboratories.
  (As we hope to show today.)
- We have performed a vigorous experimental program at FSU, including RIB experiments with RESOLUT, Spectrograph experiments and experiments with the new Clarion-2 setup.
- The FSU group has been strongly involved in “early” FRIB experiments and is developing innovative instruments for FRIB.
- The FSU experimental group is part of a “scientific ecosystem” with nuclear theory and astrophysics.
- Our lab serves as a talent-magnet for the field.

ARUNA White Paper@2023 LRP
Advancing Science, Educating Scientists, Delivering for Society

See also: Nuclear Physics News 31, 2021 - Issue 4, ARUNA White-paper at https://aruna.physics.fsu.edu



Interconnected Association of 12 laboratories
Around 200 registered users
https://aruna.physics.fsu.edu/



Studies of Nuclear Structure and Nuclear Astrophysics

Assoc. Prof.	S. Almaraz-Calderon [1,2]
Prof.	P.D. Cottle [2]
Asst. Prof.	M. Spieker [1,2]
Prof.	S.L. Tabor [2]
Asst. Prof.	V. Tripathi [2]
Prof.	I. Wiedenhöver [1,2]






1) Nuclear Astrophysics
   Fox-Lab, ATLAS, TRIUMF, FRIB
2) Nuclear Structure & Reactions
   (exotic nuclei, collective excitations, unbound states)
   Fox Lab, ATLAS, NSCL & FRIB

It takes a village: The FSU "Nuclear Network"

- Nuclear Astrophysics Group at LSU:
  J. Blackmon (Resolut, Anasen, SE-SPS), C. Deibel (SE-SPS, SABRE)
- Nuclear Structure group at ORNL
  M. Allmond, A. Macchiavelli, T. Gray (Clarion-2)
- Undergraduate College Collaborators
  L. Riley (Ursinus), A. Kuchera (Davidson)
- Nuclear Theory at FSU
  A. Volya (continuum shell-model), J. Piekarewicz (neutron stars, EOS),
  K. Fossez (ab-initio continuum models)
- Astrophysics Group at FSU
  P. Höflich (SN Ia theory), D. Collins (Structure formation theory),
  E. Hsiao (SN observ.), K. Huffenberger (CMB observ.), Nao Suzuki (SN observ.)
  M. Marengo (Stellar observ.) J. Murphy (SN-II theory)
- Hadronic Physics at FSU
  P. Eugenio, V. Crede, S. Dobbs, S. Capstick
- Relativistic Heavy Ion Physics at FSU
  A. Frawley

The Fox Lab: Research Scientists
Accelerator Staff, Shop Staff

Staff supported by NSF / supported by FSU

Dr. L.T. Baby (Accelerator Operations, Beam development, RESOLUT)

Dr. Tsz-Leung (Ryan) Tang (Computers, Data acquisition, Accelerator control systems)

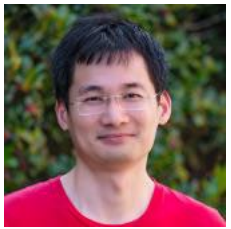
Brian Schmidt (Tandem & Ion-sources)

David Spingler (Linac & Cryogenics)

Powell Barber (Vacuum, Targets Ge-Detectors, Design)

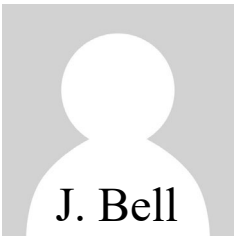
R. Boisseau, J. Aragon (Instrument Shop)

NN , J. Bell (Electronics Shop)







FSU: Fox Lab. Graduate Education

FSU graduates 2020-2023

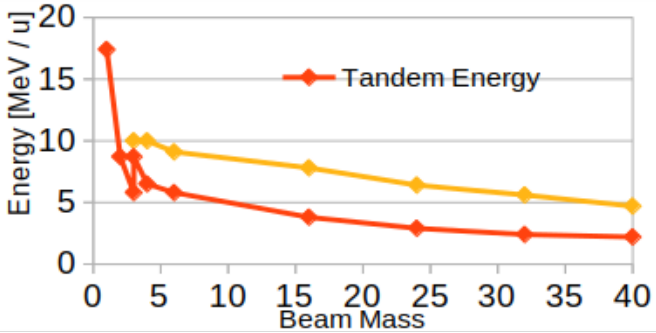
Elizabeth Rubino	Tabor	7/2020	LLNL Staff
Nate Gerken	Almaraz-Calderon	5/2021	Platinum Edge Solutions
Jesus Perello	Almaraz-Calderon	7/2021	LANL Postdoc
Benjamin Asher	Almaraz-Calderon	6/2021	PNNL Staff
Ken Hanselman	Wiedenhoever	9/2022	LANL Postdoc
Peter DeRosa	Tripathi	12/2022	(Masters) Axcelis Inc.
Gordon McCann	Wiedenhoever	6/2023	FRIB Postdoc
Caleb Benetti	Tabor	6/2023	FRIB postdoc
Ashton Morelock	Almaraz-Calderon	10/2023	UTK postdoc
Eli Temanson	Wiedenhoever	10/2023	CEA Saclay (France)
Eilens Lopez-Saavedra,	Almaraz-Calderon	11/2023	ANL postdoc

Recent / New Developments in the Group and at the Lab

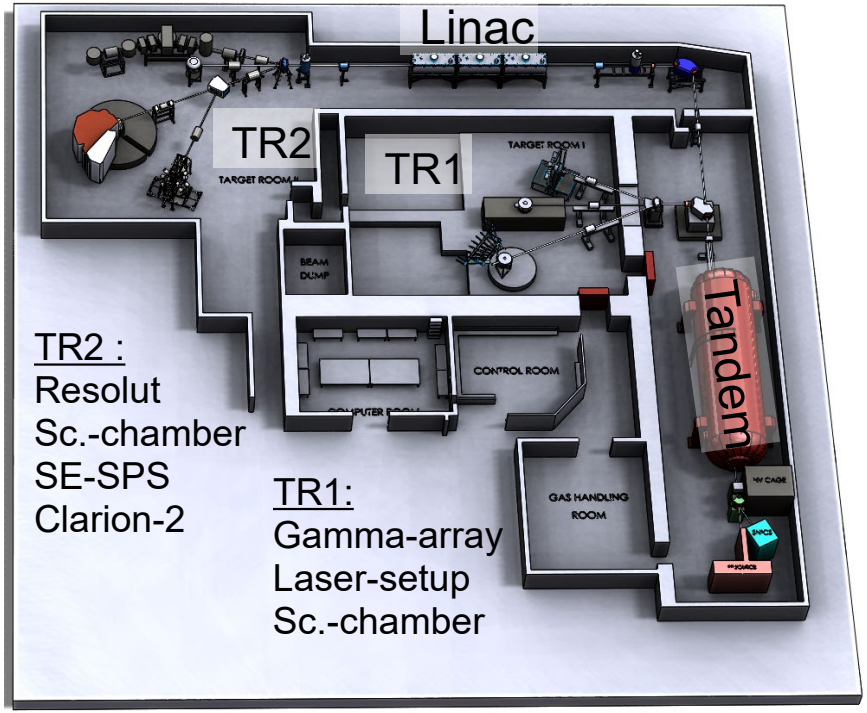
- Sergio Almaraz-Calderon was promoted to Associate Professor with tenure in Fall 2021.
- Assistant Professors Mark Spieker and Vandana Tripathi will apply for promotion and tenure this fall.
- We have built, commissioned and extensively utilized the Clarion-2 Clover Array at FSU, in collaboration with M. Allmond (ORNL). (V. Tripathi)
- We are developing particle-γ capability around the SE-SPS. (M. Spieker)
- We have a new focus area in near-threshold physics and open systems (S. Almaraz-Calderon and I. Wiedenhoever)
- We have begun a collaboration with Mayo Clinic Jacksonville's C. Beltran and K. Furutani to study biological effects of heavy-ion beams. (proposal to State of Florida pending) (S. Almaraz-Calderon)
- We are establishing a triton-beam capability at Fox Lab, which will create world-unique science opportunities (NNSA supported)

The John D. Fox Accelerator Laboratory

- 9 MV Tandem + 8 MV Linac
- Beam Energy profile

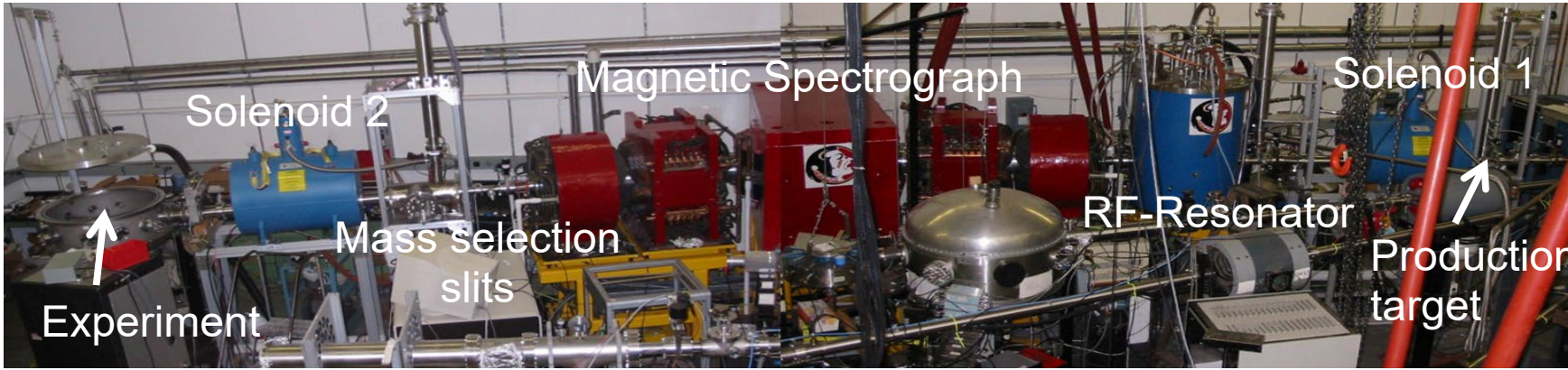


- In-flight Radioactive beams with RESOLUT
- Super-Enge Split Pole Spectrograph
- New: Clarion-2



Tandem: Pelletron-charged 9 MV FN-tandem
Linac: 14 Superconducting cavities
Niobium on Cu, Split-Ring (Atlas-design)

RESOLUT: a radioactive beam facility at FSU



In-flight production of radioactive beams in inverse kinematics,

^{7}Li(d,^{3}He) ^{6}He	18-29 MeV	~1· 10^{4} pps	(40% pure)
^{7}Li(p,n) ^{7}Be	25-35 MeV	~2· 10^{5} pps	(80% pure)
^{7}Li(d,p)^{8}Li	20-30 MeV	~5 · 10^{4} pps	(90% pure)
^{7}Li(^{3}He,n)^{8}B	30-45 MeV	~1 · 10^{4} pps	(10% pure)
^{7}Li(^{3}He,n)^{10}N	27-55 MeV	~1 · 10^{3} pps	(10% pure)
^{18}O(d,n)^{17}F	80 MeV	~2 · 10^{5} pps	(80% pure)
^{18}O(d,p)^{19}O	95 MeV	~5 · 10^{4} pps	(90% pure)
^{18}O(^{3}He,n)^{18}Ne	70 MeV	~2· 10^{4} pps	(25% pure)
^{24}Mg(d,n)^{25}Al	98 MeV	~2· 10^{4} pps	(35% pure)

Beams can be “purified” off-line by tracking / rf-correlations

FSU John D. Fox Lab; Operations data

Accelerator operates for experiments around 3000 h /year

2020: 2600 hrs (Includes Covid-19 shutdown)

Focus: Comm./Exp. of SE-SPS + Sabre

RIB Experiments

2021: 3096 hrs

Focus: Exp. with SE-SPS + Sabre

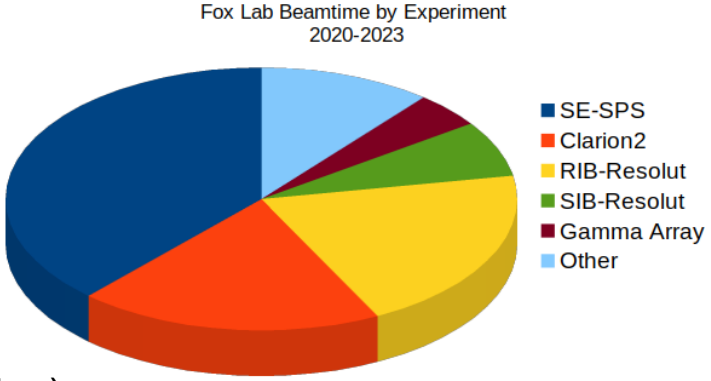
2022 3216 hrs

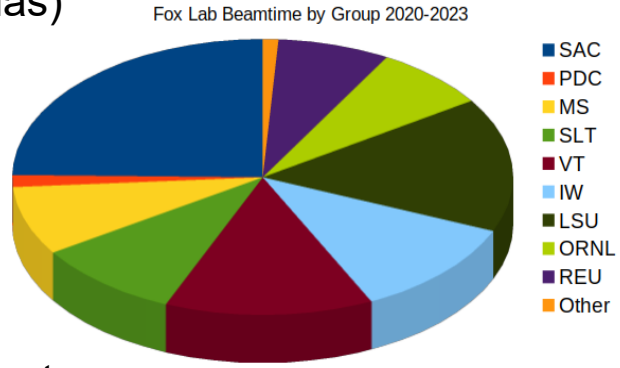
Focus: Exp. with Clarion-2 , SE-SPS

Linac upgrade (5 Resonators obtained from Atlas)

2023 2712 hrs

Focus: SE-SPS + Resolut





External groups:

LSU and ORNL dominate, close collaborators on ANASEN, SE-SPS and Clarion-2

REU-collaborators (with Cottle and Spieker) significant

Current and Proposed Budgets

	Revised Budgets 2020-2024				Proposed Budgets 2024-2028			
	Aug-20	Aug-21	Aug-22	Aug-23	Jul-24	Jul-25	Jul-26	Jul-27
Faculty #	6 (4#)	6 (4#)	6	6	6	6	6	6
Senior Personnel	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Tech Staff #	2	3	3	3	2	2	2	2
PD #	1	1	0	0	1	1	1	1
GS #	9	9	9	8	9	9	9	9
Faculty Summer	95,887#	100,689#	145,563	159,448	171,084	181,727	187,178	192,794
Grad. Students	218,430	218,430	251,183	220,632	270,027	278,128	286,472	295,066
Total Salary	633,781#	644,612#	688,414	726,132	808,136	837,801	862,845	888,640
Personnel&fringe	773,943#	787,468#	857,349	910,506	997,460	1,031,370	1,059,599	1,088,674
Other (Tuition)	44,517*	45,357*	46,230*	33,012*	100,026	101,027	102,037	103,057
OCO	100,000	98,000	0	24,073	30,000	35,000	35,000	30,000
Travel	93,000	93,000	93,000	71,640	85,000	85,000	85,000	85,000
Cryo Materials	111,000	105,000	105,000	105,000	127,528	134,842	142,918	153,657
Other Materials	132,589	125,816	119,005	89,946	216,919	227,766	239,153	248,112
REU	45,264	45,264	45,264	30,176	0	0	0	0
Indirect Cost	599,687	600,095	634,152	635,635	772,150	800,268	826,022	852,359
Total	1.9 M $	1.9 M $	1.9 M $	1.9 M $	2.33 M$	2.42 M$	2.49 M$	2.56 M$

2*Summer Salary from “startup funds” * Dean provided 5 “tuition waivers”

Budget: Observations

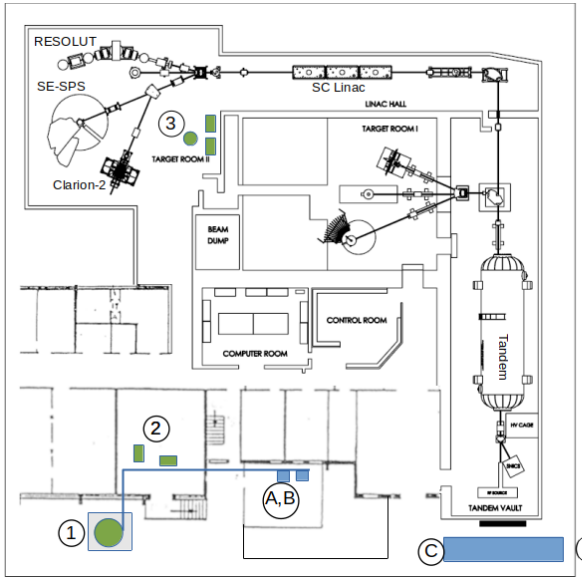
- The proposal budget is restrained, representing "constant effort" relative to the previous years.
- Comparing 2020 dollars with 2024, using 4% p.a. "general" inflation: 1.9 M$ translates to 2.24, 2.33, 2.43, 2.53 M$
- We are requesting 2.33, 2.42, 2.49, 2.56 M$ for years 1,2,3,4.
- Risk for the cryogenic operation comes from recent and projected exponential price increase for Helium => We have submitted an MRI Track-3 proposal to NSF in parallel, aiming to eliminate this risk for budgets and operations in the long term

NSF MRI Track-3 Helium recovery proposal, under review

- Fox Lab Cryosystem (1,2,3,4) is closed, but loses 40-50% of helium on warm-up.
- Helium cost has been growing über-exponentially:
  $17/ccf (2017), $30/ccf (2020), $86/ccf (2023)
- Proposal: acquire, install compressor and purifier (A,B) to recover and purify nearly all helium into cylinders (C). Total proposed budget: $335 k

Real/Projected Helium cost 2018-2025

FY	Quantity (SCF)	Liquid Equiv. (LHe)	Price incl. 54% indir.cost	Campaigns #
Helium deliveries				
2018	67,064	2,711	$17,309	2
2019	29,576	1,196	$7,634	1
2020	19,158	775	$8,703	1
2021	24,545	992	$12,043	1
2022	46,722	1,889	$29,500	1
, including accidental losses (see text)				
2019	29,576	1,196		
2021	21,000	849		
Projected without helium recovery				
2023	47,000	1,900	$62,247	2
2024	47,000	1,900	$65,359	2
2025	47,000	1,900	$68,631	2



CENTAUR – NNSA Center

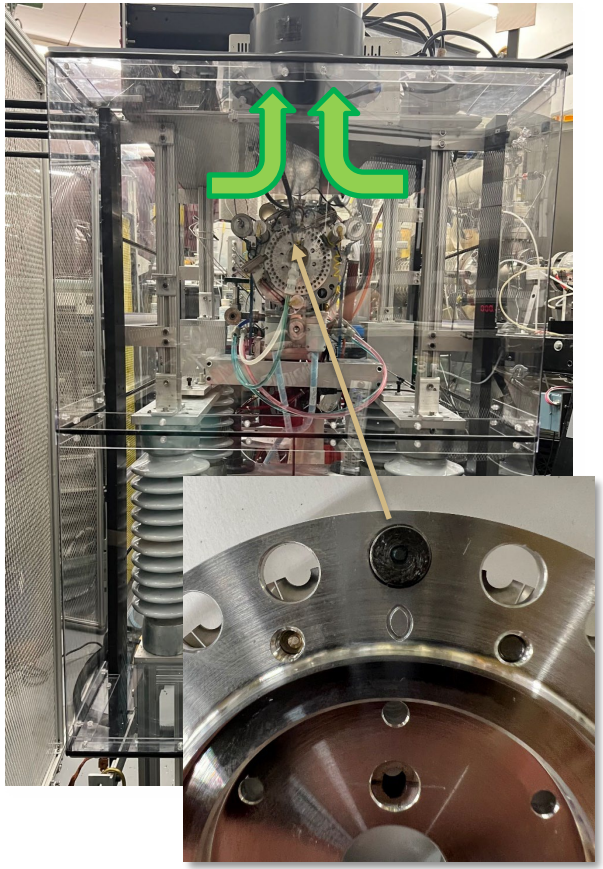
- Texas A&M as lead institution, director Sherry Yennello, with FSU, LSU, Wash U. (St. Louis), U. of Wash., U.Tenn. , U.Mass Lowell, https://centaur.tamu.edu/, part of the "Stewardship Science Academic Alliance" program at NNSA
- Centaur Round 2 beginning 1/2024, for five years, FSU receives ~$289 k annually for 3 graduate students, equipment, travel.

Research projects are synergistic with, but separate from NSF:

1. S. Almaraz-Calderon: Fission-product analysis from exotic nuclei in Encore active-target
2. P.D. Cottle: Nuclear Science Summer Camp in Bay County, Fl.
3. M. Spieker: Spectroscopy of actinide nuclei using transfer reactions.
4. V. Tripathi: Spin-correlation in fission-products to test models of fission dynamics.
5. I. Wiedenhöver: Development of a triton-beam at the FSU accelerator.

Fox Lab Tritium-Beam Project (NNSA-funded, Centaur)

- New injector to Tandem, using tritium-loaded Ti cathodes in dedicated “20-cathode SNICS”
- FSU will not handle tritium as gas.
- “Fume-hood” enclosure for set up and operation, vented above roof, continuous tritium monitoring.
- Design, procedures safety review 10/2023 ✓ D.Stracener (ORNL), J.Ashenfelter (Yale), Amy Allen (FSU)
- Design beams: 8-17 MeV, 20 nA on target
- Projected comm. 3/2024, operation 8/2024
- Creates world-unique science resource
- Workshop on scientific opportunities at FSU March 14-15 2024.



University Support; Strong leverage of NSF funds

- Significant ongoing contributions from FSU to Fox Lab:
- Recurring: Salaries of 2 instrument shop, 2 electronics shop, 1 technical, 0.75 computer personnel, 1 grants specialist
- Shop-time is free (grants pays materials)
  2 CNC mills, CNC Laithe, CNC Water-jet, Welders
- Laboratory utility-bill annually (approx.) $150,000
- Other FSU support over last grant period:
  Fume-hood enclosure for triton-beam source $90,000
  FSU Contribution to 1 Clover detector $120,000
  Misc. other equipment $95,000

FLORIDA STATE UNIVERSITY

This proposal represents an invigorated FSU group, including two Assistant Professors with strong programs at FSU and FRIB.

The FSU laboratory is a pillar of graduate education in the USA -

and undergraduate research as well.

The SE-SPS and Clarion-2 foster growing external collaborations,
the triton beam will add more.

We are thankful for the NSF-support, which has allowed us to get here.

… and are asking for the funding to fulfill the potential of
the laboratory and the scientists around it.